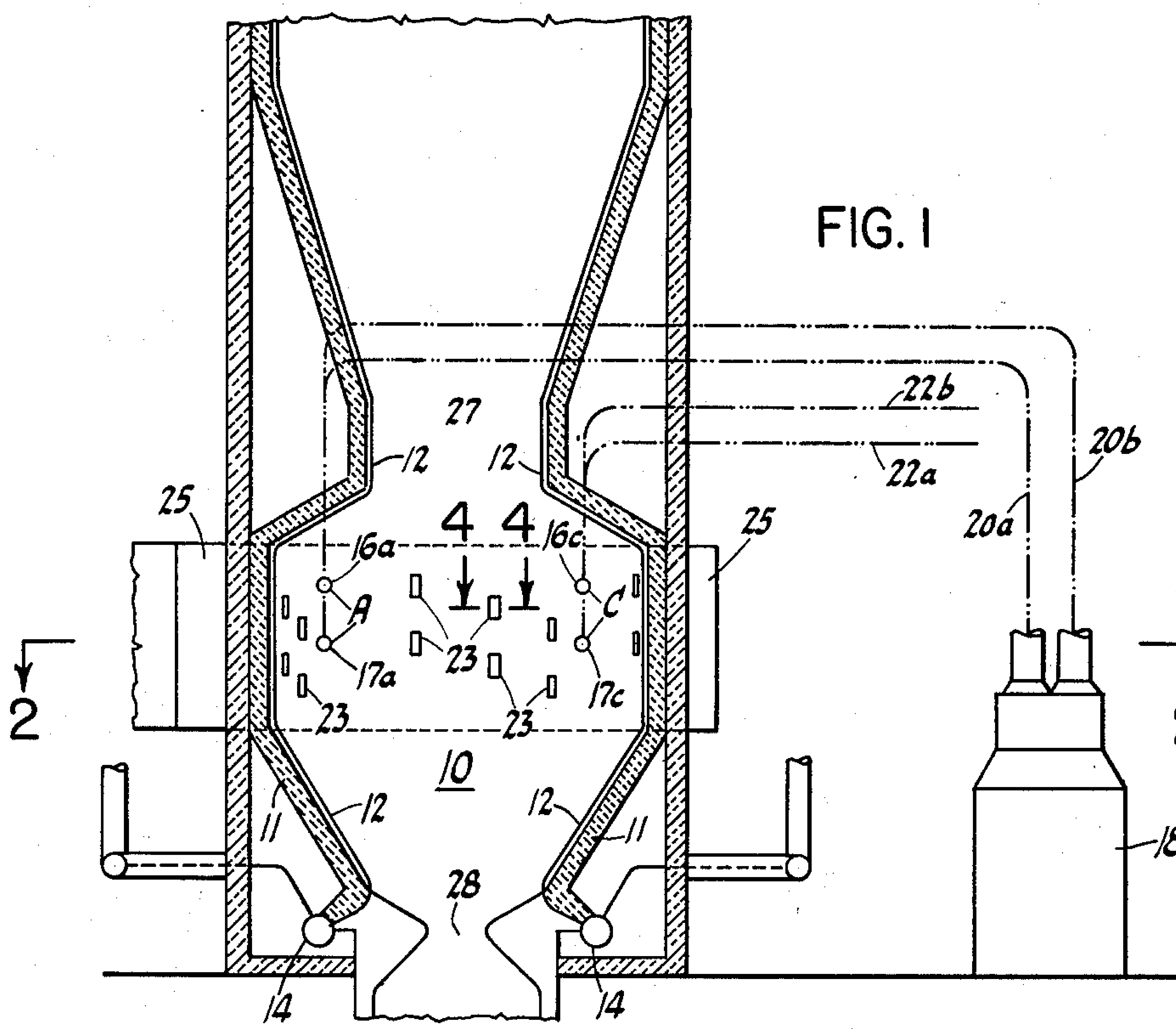


FIG. 1

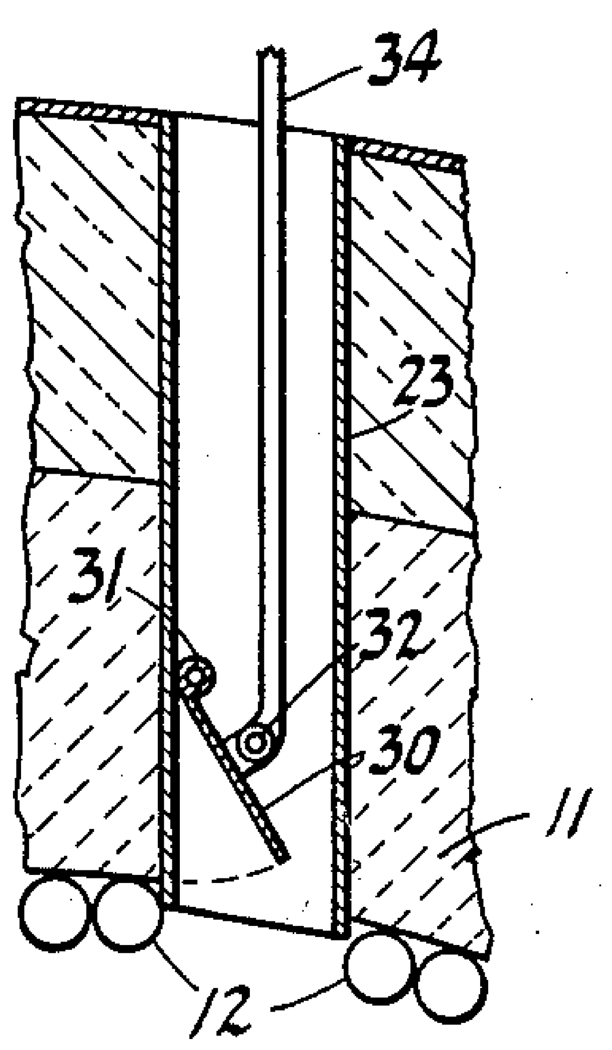


FIG. 4

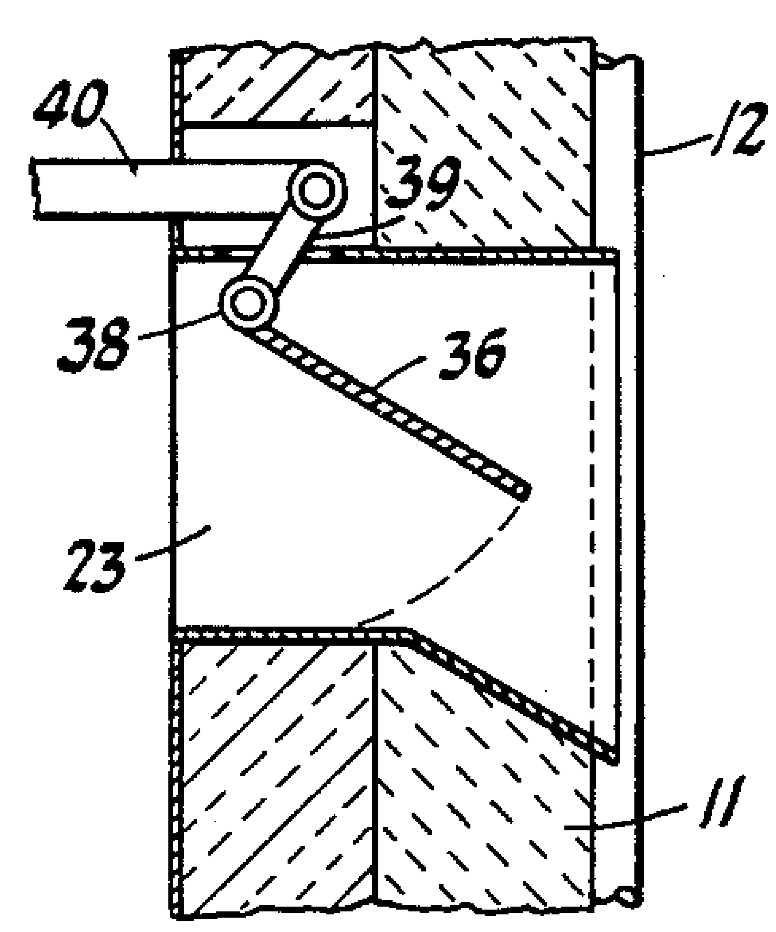


FIG. 5

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April 27, 1965 G. STEINERT 3,180,289

SLAGGING CYCLONE FURNACE

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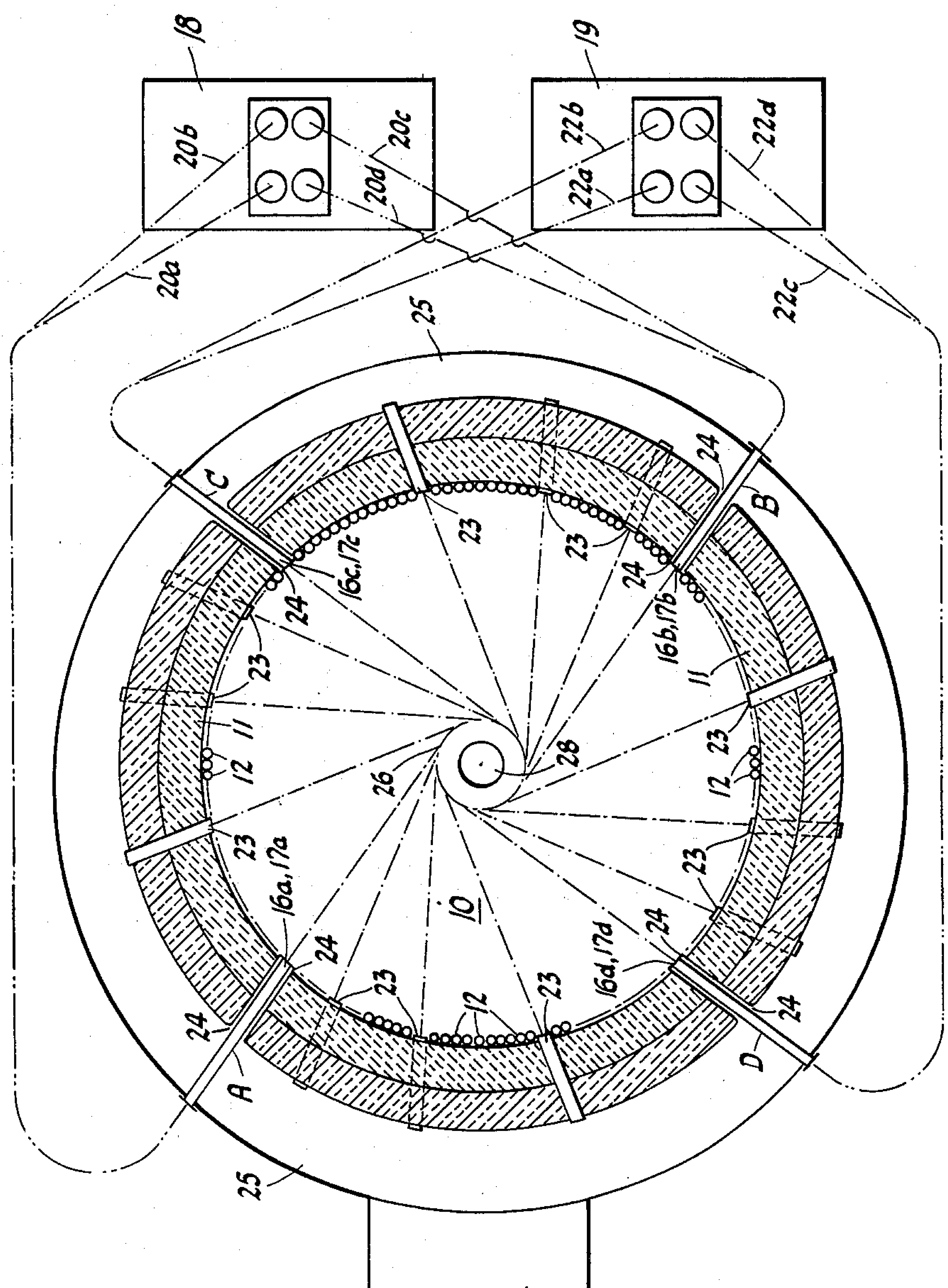


FIG.2

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SLAGGING CYCLONE FURNACE

Filed March 20, 1963 3 Sheets-Sheet 3

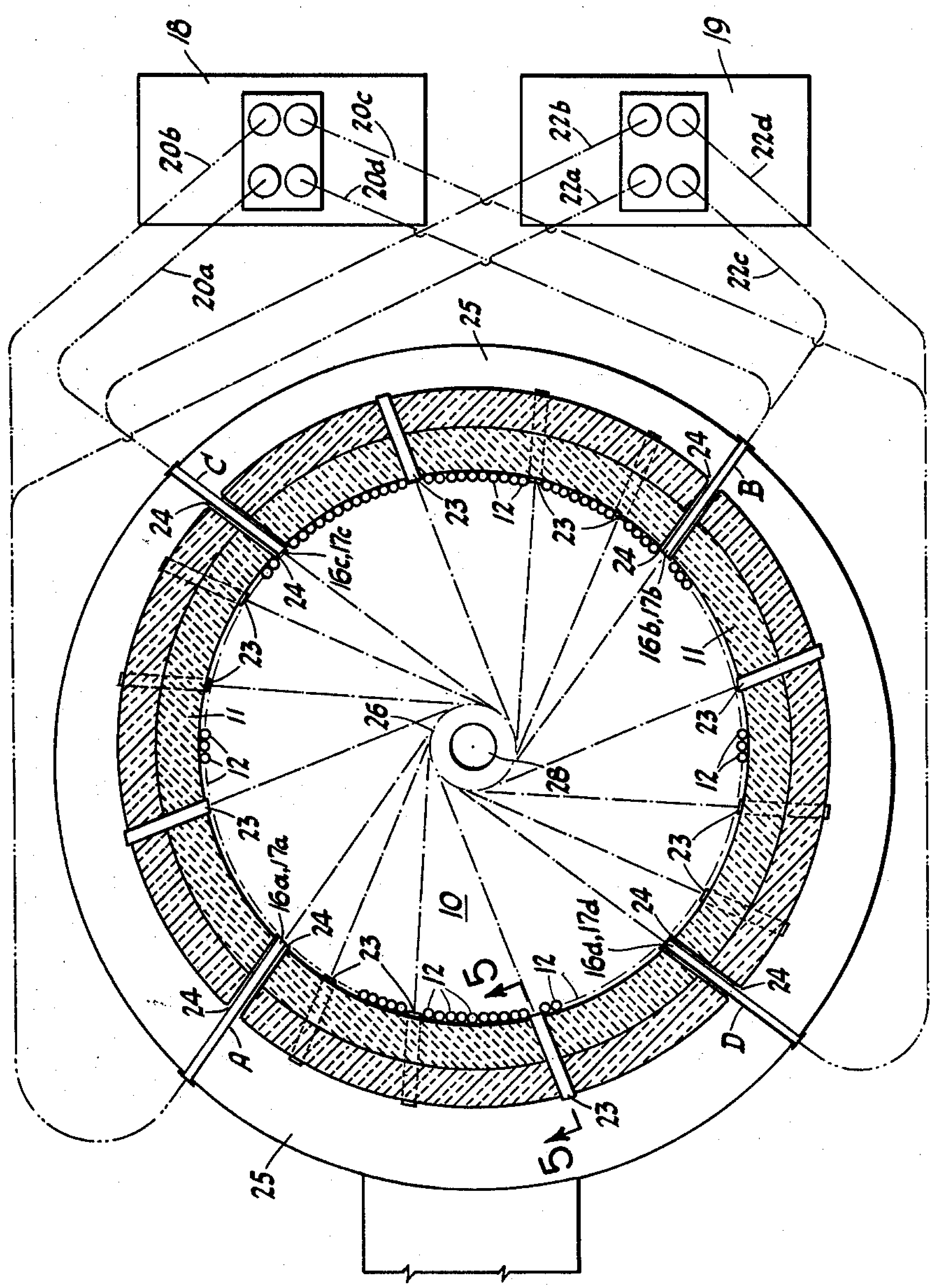


FIG.3

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3,180,289
Patented Apr. 27, 1965



3,180,289

# SLAGGING CYCLONE FURNACE

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19 Claims. (Cl. 110—28)

The invention relates to a cyclone furnace from which the ash is discharged in a fluid state before being solidified in granular form. The invention is more particularly directed to an upright cyclone furnace having a vertical axis, with the walls of the combustion chamber thereof being lined with water carrying tubes and into which fuel is being fed through a plurality of fuel nozzles circumferentially spaced with the fuel streams being tangentially directed toward the surface of an imaginary firing cylinder.

The requirement of preventing fly ash from polluting the atmosphere is in many cases the reason why cyclone slagging bottom furnaces are preferred, since when burning pulverized fuel in these furnaces almost the entire ash content leaves the furnace in liquid form rather than through the chimney as fly ash. An additional advantage of the cyclone slagging bottom furnace is that these furnaces can be operated with a low percentage of excess air because of the extremely high furnace temperatures that must necessarily be maintained in a slagging cyclone type furnace. It is for this reason that dry gas losses are much lower and burning efficiency considerably higher in cyclone slagging bottom furnaces than in any other pulverized fuel fired furnaces.

When considering however the experience gained from operating a large number of slagging type furnaces over a considerable time, it has been found that the advantages due to slagging of the ash and due to the higher burning efficiency are bought at a high price. It was found that in the slagging bottom furnaces not all fuel is being burned with a sufficient amount of excess air but that a significant quantity of fuel is being burned in the vicinity of the furnace wall under conditions which are characterized by lack of oxygen, thereby causing corrosion of the furnace chamber cooling tubes. This corrosion necessitates the periodic shutting down of these furnaces for replacement of tubes and repair of the furnace lining. Such interruptions are very costly and are obviously undesirable.

It is accordingly an object of the invention to prevent or greatly reduce corrosion of the wall tubes of a slagging bottom cyclone furnace by discouraging the burning of fuel in zones adjacent such tubes where lack of oxygen may occur.

These regions of low oxygen are found primarily at locations between fuel nozzles, where fuel particles have succeeded in breaking out of the rotating mass of burning gases. These fuel particles accordingly continue burning along the wall of the furnace chamber in a reduced oxygen atmosphere.

In accordance with the invention elimination of this undesirable condition can be achieved by introducing only a minor portion of the excess air in conventionally known manner, i.e. in the vicinity of the burners, and introducing the remaining major portion of the secondary air at a plurality of points selectively located between the fuel admission nozzles.

In cyclone type furnaces of designs as heretofore practiced in the art, pulverized fuel particles escaping from the periphery of the rotating gas mass, only have to traverse one fuel and air stream in the direction of rotation to reach the furnace chamber wall. However, in



accordance with the invention, these particles now will meet in addition one or more air streams thereby causing the particles to re-enter the rotating gas mass where greater opportunity exists for the fuel particles to burn in an atmosphere containing larger amounts of oxygen. Although in the method of burning as disclosed herein the total kinetic energy of all the air streams may not be significantly larger, the secondary air is now distributed in such a manner that fuel particles escaping from the rotating gas mass meet several more or less radially directed air streams which cause these fuel particles to return to the rotating gas mass.

The desirable effect of the invention can be enhanced by increasing the number of air nozzles located between fuel nozzles. In addition this effect can be accelerated by utilizing successively higher pressures in the air nozzles in the direction of rotation. A similar beneficial effect can be achieved by gradually decreasing the spacing between secondary air nozzles in direction of rotation of the gases. Obviously, some or all of these improvements can be employed in one and the same installation.

Furthermore experience has shown that the fuel particles escaping from the rotating gas mass are of larger size than those remaining within that mass and tend to sink towards the furnace bottom. In accordance with the invention the air nozzles are therefore located on a downwardly slanting line or a line which takes the form of a spiral thereby following the path of the heavier fuel particles that are sinking towards the lower part of the furnace. In this manner these particles are being caught in one of the secondary air streams, and are thereby prevented from burning in a reducing atmosphere along the furnace wall tubes by being urged instead into the rotating gas mass.

To maintain the air velocity sufficiently high for efficient combustion at low load, tongue-like dampers are being provided in the secondary air nozzles for the purpose of altering the cross-sectional flow area thereof.

In furnaces where each fuel introduction comprises two or more fuel nozzles arranged one above the other, with these fuel nozzles receiving fuel from a common source, for example a pulverizer, the secondary air dampers are in accordance with the invention hingedly supported on a vertical axis which permits the cross-sectional area to be changed horizontally.

If the rate of combustion in a furnace organization of this type is being reduced by lowering the delivery capacity of the pulverizer, the elevational location of the flame envelope or flame cylinder in the furnace chamber does not change appreciably. Accordingly the secondary air flow must be delivered at substantially the same elevation in the furnace, although the quantity of air may be reduced.

In other furnaces where each fuel introduction comprises two or more fuel nozzles arranged one above the other, but wherein each fuel nozzle receives fuel from a different source, such as for instance from a different pulverizer or mill, the secondary air dampers are, in accordance with the invention, hingedly supported on a horizontal axis, which permits the cross-sectional area to be changed vertically.

This is necessary since in furnaces of this type a reduction of the pulverizer capacity or a shutting down of one of the pulverizers causes the flame envelope or flame cylinder to alter its vertical location within the furnace chamber. Accordingly the elevation of the secondary air streams must be adapted to the location of the flame so that combustion may continue under the most favorable conditions. Furthermore it is desirable to subdivide the secondary air nozzles in accordance with the number of vertically spaced fuel nozzles.

With the aforementioned objects in view the invention comprises a method of operation, construction and combination of elements of a cyclone furnace in such a manner as to attain the results desired as hereinafter more particularly set forth in the following detailed description of an illustrative embodiment, said embodiment being shown by the accompanying drawings wherein:

FIG. 1 is an elevational section of a slagging cyclone type furace incorporating the invention;

FIG. 2 is a cross sectional view taken on line 2—2 of FIG. 1 showing a furnace wherein each fuel burner location receives fuel from only one fuel source or pulverizer;

FIG. 3 is a cross sectional view similar to FIG. 2, however indicating a furnace wherein each fuel burner location receives fuel from more than one source or pulverizer;

FIG. 4 is a partial cross section taken on line 4—4 of FIG. 1 illustrating the manner in which a secondary air nozzle is provided with a damper hingedly supported on a vertical axis; and

FIG. 5 is a vertical cross section taken on line 5—5 of FIG. 3 showing the manner in which a secondary air nozzle is provided with a damper hingedly supported on a horizontal axis.

The fuel burning organization illustrated in FIG. 1 comprises a combustion chamber **10**, having a substantially cylindrical wall of heat resisting refractory material **11** the fire side thereof being lined with water carrying and steam generating tubes **12** receiving water from a circular header **14** which in turn is supplied by feedwater from a conventional source, not shown. Fuel and primary air is discharged into the furnace chamber by way of two sets of fuel nozzles or burners. These nozzles are arranged at four burner locations A, B, C and D, circumferentially spaced with each burner location being provided with two burner nozzles arranged one above the other. Thus burner locations A, B, C and D are provided with upper burners **16*a*, 16*b*, 16*c*** and **16*d***, respectively, with lower burners **17*a*, 17*b* 17*c*** and **17*d***, respectively. These fuel burners are organized to receive pulverized fuel and primary air from pulverizers **18** and **19** by way of fuel pipes **20*a*, 20*b*, 20*c*, 20*d*** and **22*a*, 22*b*, 22*c*, 22*d***, respectively. A major portion of the secondary air is introduced into the furnace in accordance with the invention through secondary air nozzles **23** with these air nozzles being circumferentially spaced between the fuel nozzle locations A, B, C and D. On the other hand a relatively minor portion of the secondary air is introduced adjacent or in surrounding relation with the fuel nozzles such as through conduits **24**. The immediate source of the secondary air to which conduits **24** and nozzles **23** are connected, is an air duct or plenum chamber **25** which circumferentially surrounds the chamber **10**, and which is in communication with a supply of heater air, not shown. As indicated in FIGS. 2 and 3 the fuel streams and air streams are directed tangentially to the surface of an imaginary firing cylinder **26** centrally located within the combustion chamber. A mass of combustion gases is produced by the burning of the fuel which gases rotate in direction of the arrow along a spiral path and which leave the furnace chamber by way of throat-like outlet **27** and continue on upwardly passing over other heat absorbing surfaces, not shown. The temperature in the furnace gases exceeds the fusion temperature of the ash in the fuel thereby causing the ash to assume liquid form. Due to rotation of the gases the liquid ash droplets are expelled by centrifugal force, adhere to the side walls of the furnace chamber and eventually flow down these walls, through a slag outlet **28** and into a cooling chamber from which these ashes are removed in granular form.

As earlier set forth herein cyclone type furnaces are operated at a relatively high temperature and with relatively low excess air. Due to the cyclone action of the gases a deficiency of oxygen is experienced along the wall of the furnace chamber causing the burning of some



of the fuel in a reduced atmosphere. Such burning has been found to be the cause of considerable corrosion damage to the cooling tubes **12** of the furnace **10** and requires the shutting down of the furnace at periodic intervals for the purpose of replacing damaged portions of the furnace wall.

In accordance with the invention the undesirable burning of fuel particles in the neighborhood of the wall and corrosion damage of the tubes **12** is greatly reduced by providing introduction of the major portion of the secondary air by way of secondary air nozzles **23** circumferentially located between fuel nozzles **16*a*, 16*b*, 16*c*, 16*d*** and **17*a*, 17*b*, 17*c*, 17*d***. As earlier pointed out this will cause any fuel particles having escaped from the rotating gas mass to be recaptured by the central body of gases where a higher percentage of oxygen is available for burning.

It was found to be especially advantageous to locate the secondary fuel nozzles **23** in such a manner that the spacing thereof decreases in direction of gas rotation such as illustrated in FIGS. 2 and 3. Furthermore it was found to be of great advantage to introduce only a minor portion of the secondary air in the immediate neighborhood of the fuel nozzles such as by conduits **24** and provide the furnace with the remaining major portion of the secondary air by way of the secondary air nozzles **23** circumferentially located between the fuel nozzles **16*a*, 16*b*, 16*c*, 16*d*** and **17*a*, 17*b*, 17*c*, 17*d***. As earlier pointed out herein a further improvement resides in increasing the secondary air pressure, air flow and velocity in the secondary air nozzles **23** progressively in direction of gas rotation.

It was found that the heavier fuel particles are most likely to escape from the gas mass and that these particles have a tendency of following a declining spiral path downwardly towards the bottom of the furnace. Accordingly the invention provides for locating the secondary air nozzles **23** similarly on a line sloping downwardly at a moderate pitch in direction of gas rotation, such as for instance on a spiral line.

In FIGS. 1 and 2 a fuel burning apparatus is illustrated in which pulverizer or mill **18** supplies only two oppositely arranged burner locations A and B, or burner nozzles **16*a*, 17*a***, and **16*b*, 17*b***, respectively. Likewise the second mill **19** supplies fuel to the other two burner locations C and D comprising burners **16*c*, 17*c*** and **16*d*, 17*d***, respectively.

Since in this type of firing the elevation of the fire ball or flame envelope does not change with change of load, secondary air outlets **23** are provided with dampers **30**, as shown in FIG. 4, which are hingedly supported on a vertical axis **31**, with these dampers and the opening of the air nozzles being horizontally adjusted by means of brackets **32** and rods **34**.

In FIG. 3, on the other hand, a fuel burning apparatus is illustrated in which mill **18** supplies the upper burners **16*a*, 16*b*, 16*c*** and **16*d*** of all four burner locations A, B, C and D, respectively, and in which mill **19** supplies the lower burners **17*a*, 17*b*, 17*c*** and **17*d*** of all four burner locations A, B, C and D, respectively. Upon a reduction in load such as by shutting down one of the pulverizers **18** or **19**, the elevation of the fire ball in the furnace chamber changes. Accordingly the secondary air outlets **23** are provided with dampers which are hingedly supported on a horizontal axis, permitting not only the maintaining of the outlet velocity of the air at lower loads but also affording a possibility of changing the direction of the secondary air streams from the horizontal. This is illustratively shown in FIG. 5 with damper **36** being hinged at **38** and with the damper as well as the secondary air outlet opening being vertically adjustable by means of bracket **39** and rod **40**.

From the aforesaid it is evident that I have provided an improved cyclone type furnace for burning pulverized fuel, in which corrosion of the wall surface due to excessive burning of the fuel along and adjacent the fluid cooled walls is largely prevented by one or more of the following features:

(1) Discharging the major portion of the secondary air at locations and by way of air nozzles or air outlets located between the circumferentially spaced fuel burners;

(2) Locating the secondary air outlets on a line slightly sloping downwardly in direction of gas rotation, or on a spiral line;

(3) Increasing the secondary air velocity, air quantity or air pressure in the air nozzles in direction of gas rotation; and

(4) Providing the secondary air outlets with directional dampers which are vertically or horizontally hinged depending on whether the elevation of the flame envelope in the combustion chamber changes or remains stationary with a change in burning rate; and

(5) Locating the secondary air outlets between each pair of burner locations with the spacing between the secondary air outlets decreasing in directions of gas rotation.

While I have illustrated and described two preferred embodiments of my invention, it is to be understood that such are merely illustrative and not restrictive and that variations and modifications may be made therein without departing from the spirit and scope of the invention. I therefore do not wish to be limited to the precise details set forth but desire to avail myself of such changes as fall within the purview of my invention.

I claim:

1. The method of burning pulverized fuel suspended in air within an upright cyclone type slagging bottom furnace chamber lined with heat absorbing tubes and being provided with a plurality of circumferentially spaced fuel nozzles in the upright wall of the chamber at a given elevation, and air nozzles interspaced between said fuel nozzles, the steps comprising:

(1) burning fuel in said chamber by introducing thereinto through said spaced fuel nozzles separate streams of pulverized fuel suspended in primary air in directions tangential to an axially oriented imaginary firing cylinder thereby producing a mass of burning and rotating gas and fuel particles;

(2) introducing a minor portion of the secondary air into said chamber in flanking relation with the entering portion of each of said tangentially directed fuel and primary air streams;

(3) introducing at a controllable pressure the remaining major portion of the secondary air into said chamber in streams at a plurality of points circumferentially spaced between two adjacent fuel and primary air streams.

2. The method as defined in claim 1, with the additional step of controllably deflecting said major secondary air streams in a horizontal plane.

3. The method as defined in claim 1, with the additional step of increasing said controllable pressure at said plurality of points in direction of rotation of said mass of gas and fuel particles.

4. The method as defined in claim 3, with the additional step of controllably deflecting said major secondary air streams in a downward direction.

5. The method of burning pulverized fuel suspended in air within an upright cyclone type slagging bottom furnace chamber lined with heat absorbing tubes and being provided with a plurality of circumferentially spaced fuel nozzles in the upright wall of the chamber at a given elevation, and air nozzles interspaced between said fuel nozzles, the steps comprising:

(1) burning fuel in said chamber by introducing through said spaced fuel nozzles separate streams of burning pulverized fuel suspended in primary air in directions tangential to an axially oriented imaginary firing cylinder thereby producing a mass of burning and rotating gas and fuel particles;

(2) introducing a minor portion of the secondary air into said chamber in flanking relation with the entering portion of each of said tangentially directed fuel and primary air streams;

(3) introducing at a controllable pressure the remaining major portion of the secondary air into said chamber in streams at a plurality of points circumferentially spaced between two adjacent fuel and primary air streams, with the spacing of said secondary air streams decreasing in direction of rotation.

6. The method as defined in claim 5, with the additional step of controllably deflecting said major secondary air streams in a horizontal plane.

7. The method as defined in claim 5, with the additional step of increasing said controllable pressure at said plurality of points in direction of rotation of said mass of gas and fuel particles.

8. The method as defined in claim 7 in which said major secondary air streams are controllably deflected in a downward direction.

9. The method of burning pulverized fuel suspended in air within an upright cyclone type slagging bottom furnace chamber lined with heat absorbing tubes and being provided with a plurality of circumferentially spaced fuel nozzles in the upright wall of the chamber at a given elevation, and air nozzles interspaced between said fuel nozzles, the steps comprising:

(1) burning fuel in said chamber by introducing thereinto through said spaced fuel nozzles separate streams of pulverized fuel suspended in primary air in directions tangential to an axially oriented imaginary firing cylinder thereby producing a mass of burning and rotating gas and fuel particles;

(2) introducing a minor portion of the secondary air into said chamber in flanking relation with the entering portion of each of said tangentially directed fuel and primary air streams;

(3) introducing at a controllable pressure the remaining major portion of the secondary air into said chamber in streams at a plurality of points circumferentially spaced between two adjacent fuel and primary air streams, said points being located on an imaginary spiral line descending from said elevation.

10. The method as defined in claim 9, with the additional step of controllably deflecting said major secondary air streams in a horizontal plane.

11. The method as defined in claim 9, with the additional step of increasing said controllable pressure at said plurality of points in direction of rotation of said mass of gas and fuel particles.

12. The method as defined in claim 11, with the additional step of controllably deflecting said major secondary air streams in a downward direction.

13. The method of burning pulverized fuel suspended in air within an upright cyclone type slagging bottom furnace chamber lined with heat absorbing tubes and being provided with a plurality of circumferentially spaced fuel nozzles in the upright wall of the chamber at a given elevation, and air nozzles interspaced between said fuel nozzles, the steps comprising:

(1) burning fuel in said chamber by introducing thereinto through said spaced fuel nozzles separate streams of pulverized fuel suspended in primary air in direction tangential to an axially oriented imaginary firing cylinder thereby producing a mass of burning and rotating gas and fuel particles;

(2) introducing a minor portion of the secondary air into said chamber in flanking relation with the entering portion of each of said tangentially directed fuel and primary air streams;

(3) introducing at a controllable pressure the remaining major portion of the secondary air into said chamber in streams at a plurality of points circum-

ferentially spaced between two adjacent fuel and primary air streams, with the spacing of said secondary air streams decreasing in direction of rotation and begin located on an imaginary spiral line descending from said elevation.

14. The method as defined in claim 13, with the additional step of controllably deflecting said major secondary air streams in a horizontal plane.

15. The method as defined in claim 13, with the additional step of increasing said controllable pressure at said plurality of points in direction of rotation of said mass of gas and fuel particles.

16. The method as defined in claim 15, with the additional step of controllable deflecting said major secondary air streams in a downward direction.

17. In a pulverized fuel burning plant, a first and a second source of pulverized fuel; a vertically elongated combustion chamber defined by upright wall means; a first and a second set of burners for discharging said pulverized fuel in directions tangential to an imaginary firing cylinder located within said chamber and having a vertical axis, and for burning said fuel and producing a rotating mass of combustion gases; said first set of burners being located in said wall means at a higher elevation than said second set of burners and being circumferentially spaced; the burners of said second set likewise being circumferentially spaced; a plurality of air inlet means for introducing air for combustion into said chamber; said plurality of inlets constituting a whole number multiple of the number of burners in each set and being circumferentially spaced; conduit means for connecting some of the burners of said first set to said first source of fuel and the remaining burners of said first set to said second source of fuel for delivery of fuel to said chamber; conduit means for connecting some of the burners of said second set to said second surce of fuel and the remaining burners of said second set to said first source of fuel for delivery of fuel to said chamber; and damper means hingedly connected to said inlet means for rotation about a vertical axis, whereby to deflect said air in directions away from the vertical.

18. In a pulverized fuel burning plant, a first and a second source of pulverized fuel; a vertically elongated combustion chamber defined by upright wall means; a first and a second set of burners for discharging said pulverized fuel in directions tangential to an imaginary firing cylinder located within said chamber and having a vertical axis, and for burning said fuel and producing a rotating mass of combustion gases; said first set of



burners being located in said wall means at a higher elevation than said second set of burners and being circumferentially spaced; the burners of said second set likewise being circumferentially spaced; a plurality of air inlet means for introducing air for combustion into said chamber; said plurality of inlets constituting a whole number multiple of the number of burners in each set and being circumferentially spaced; conduit means for connecting the burners of said first set to said first source of fuel for delivery of fuel to said chamber; conduit means for connecting the burners of said second set to said second source of fuel for delivery of fuel to said chamber; and damper means hingedly connected to said inlet means for rotation about a horizontal axis, whereby to deflect said air in directions away from the horizontal.

19. In a pulverized fuel burning plant, a source of pulverized fuel; a vertically elongated combustion chamber defined by upright wall means; a set of individual burners located in said upright wall means, for discharging said pulverized fuel in separate streams and directions tangential to an imaginary firing cylinder located within said chamber and having a vertical axis, and for burning said fuel and producing a rotating mass of combustion gases; the individual burners of said set being circumferentially spared; a plurality of air inlet means for introducing air for combustion into said chamber; said plurality or inlets constituting a whole number multiple of the number of individual burners in each set and being circumferentially spaced between said burners; the spacing of said inlets between said burners decreasing in direction of gas rotation; said inlets being located on a peripheral line sloping downwardly in direction of gas rotation; conduit means for connecting the burners of said set to said source of fuel for delivery of fuel to said chamber; and damper means hingedly connected to said inlet means for rotation about an axis, whereby to controllably deflect said air.


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